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Shorebirds of the Kimberley Coast – Populations, key sites, trends and threats

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Abstract

The tidal flats of the Kimberley coast support the largest populations of migratory shorebirds in Australia. In this paper we review and discuss population sizes of all 41 shorebird species occurring on the Kimberley coastlines, and summarise the importance of the region in an international context. The Kimberley coastline is used by *c.* 3.7 million shorebirds, including *c.* 635,000 migrants from the northern hemisphere and *c.* 16,000 Australian-bred resident shorebirds which forage on the tidal flats of the Kimberley coast. A further *c.* 3.06 million migratory shorebirds from near-coastal grasslands (Oriental Plover, Little Curlew and Oriental Pratincoles) use roosts on the Kimberley coast at times. Most coast-dependent shorebirds of the Kimberley are concentrated in a small number of sites. Eighty-mile Beach and Roebuck Bay are the most important two sites; they have the highest numbers of birds, and the greatest diversity of species occurring in internationally significant numbers. Internationally important numbers of several species occur on some offshore islands (Adele Island, Ashmore Reef and the Lacepedes), including several species (*e.g.* Lesser Sand Plover, Grey Plover, Grey-tailed Tattler and Ruddy Turnstone) which are disproportionately abundant on offshore islands when compared to the mainland. Although most of the key shorebird sites on the Kimberley coast are remote and have not been greatly affected by humans, there are indications that populations of many migratory species on the Kimberley coast are declining, probably because of habitat loss in the east Asian areas where they stage on migration. Continued and enhanced monitoring of shorebirds in the Kimberley that contributes strategically to the conservation management of this group is strongly recommended.

Keywords: shorebirds, Kimberley Coast, tidal flats

Introduction

Scope of this paper

Shorebirds, also known as 'waders', are smallish, mostly long-legged birds in the avian order Charadriiformes. They include the plovers and lapwings (family Charadriidae); curlews, godwits, snipe and sandpipers (family Scolopacidae); the oystercatchers (family Haematopidae); stilts and avocets (family Recurvirostridae); stone-curlews (family Burhinidae); jacanas (family Jacanidae) and painted snipe (family Rostratulidae). Most shorebird species are dependent on coastal or freshwater wetlands, and many species (especially in the families Charadriidae and Scolopacidae) are strongly migratory, breeding in the far-northern hemisphere and migrating thousands of kilometres to distant non-breeding grounds. Australia is the regular non-breeding destination for about 38 migrant species, and the breeding region for 18 resident shorebird species; *c.* 23 further species have occurred as vagrants (Marchant & Higgins 1993, Higgins & Davies 1996, Christides & Boles 2008).

Shorebirds are studied by a community of amateur and professional ornithologists in Australia, inspired by the attractive appearance of the birds themselves, their spectacular migrations, and concern about the conservation threats that they face. Many non-breeding shorebird populations in Australia are declining (Gosbell and Clemens 2006; Wilson *et al.* 2011), despite the facts that migratory shorebirds are protected under the

Environment Protection and Biodiversity Conservation Act 1993, and that Australia is signatory to a number of international conservation agreements which list migratory shorebirds. These include the Ramsar Convention on Wetlands of International Importance (Department of Foreign Affairs 1975), the Japan – Australia Migratory Bird Agreement (Department of Foreign Affairs 1981), the China – Australia Migratory Bird Agreement (Department of Foreign Affairs 1988) and the Republic of Korea – Australia Migratory Bird Agreement (Department of Foreign Affairs 2007).

North Western Australia leapt to prominence in the shorebird biology world in the early 1980s. The Royal Australasian Ornithologists Union (now Birds Australia) was in the early stages of the first national project to assess shorebird populations in Australia when reports emerged of extraordinarily high shorebird numbers in Roebuck Bay and on the shores of Eighty-mile Beach (Minton & Martindale 1982, Minton 2006). Follow-up surveying revealed these sites to be the most important shorebird sites in Australia, and the most important non-breeding grounds known for shorebirds in the East Asian – Australasian Flyway (Lane 1987; Watkins 1993; Bamford *et al.* 2008).

In this paper, we draw together results from shorebird surveys carried out along the Kimberley coast to present a revised estimate of the number of shorebirds that occur in the region. We aim to present estimates based on recent surveys; it cannot be assumed that all historical counts are acceptable estimates of current numbers, given that there is emerging evidence that many shorebird species are declining in Australia (*e.g.* Gosbell and Clemens 2006). We restrict our attention to high tide roosts on the coast from Eighty-mile Beach to the border of Western Australia and the Northern Territory, including offshore islands (Fig. 1). Gulls and terns were usually counted in the surveys we summarise, but the surveys were designed to optimise counts of shorebirds rather than seabirds; we have excluded gulls and terns from this paper. Important shorebird populations occur in the Port Hedland region, and further south on the Pilbara coast. Although these regions are sometimes aggregated as 'North Western Australia' in the shorebird literature, we have not included them in this paper as they are far outside the Kimberley region. Nor have we attempted to summarise shorebird numbers on the freshwater wetlands of the Kimberley. Although shorebird surveys have not been conducted systematically in the area for long enough to carry out a comprehensive analysis of population trends, we present some preliminary results indicative of ongoing declines, and discuss potential threats to shorebirds of the Kimberley coastline.

Previous shorebird studies on the Kimberley coast

Since 1981, Roebuck Bay has become an international centre for shorebird research, with the shorebird populations there stimulating a long series of expeditions by the Australasian Wader Studies Group (AWSG) and the establishment of Broome Bird Observatory, and these in turn stimulating the establishment of a number of studies by visiting and resident researchers (Minton 2006). Banding studies by the AWSG, now supplemented by more intensive studies by post-graduate students and the Global Flyway Network (an international partnership of researchers carrying out long-term demographic studies of long-distance-migrant shorebirds, http://www.globalflywaynetwork.com.au/), have revealed the essentials of the migration routes and strategies of many of the shorebird species of Roebuck Bay and Eighty-mile Beach; these essentials are presumably shared by shorebirds at other sites of the Kimberley coast. Most migratory species in the region are believed to use North Western Australia as a non-breeding area, where adults stay for several months (from about late August/September to March/April, exact timing differing between species) while carrying out their annual flight-feather moult (Minton *et al.* 2006). In a few species, such as Sharp-tailed Sandpiper *Calidris acuminata*, some adults stage on the coast of the Kimberley before migrating further south. Many migratory shorebird species on the Kimberley coast have delayed maturity, and after arriving in North Western Australia within 3–5 months of fledging in the northern hemisphere, they remain there for 1–3 years before they first attempt to migrate north (Rogers *et al.* 2006a). As a result, migratory shorebirds can be found on the Kimberley coast at all times of year, but numbers are lowest during the dry season (about May to early August) when adults are breeding in the northern hemisphere and only immature shorebirds remain in Australia.

Recaptures, resightings and remote observations of shorebirds that were banded, leg-flagged or satellite-tagged in North Western Australia have also revealed a great deal about the migration routes of our migratory shorebirds. Most species migrate in extremely long direct flights of several thousand kilometres. For example, leg-flag resightings and the correspondence between departure dates from Roebuck Bay and arrival dates in the Yellow Sea, indicate that Red Knots *Calidris canutus* and Great Knots *Calidris tenuirostris* migrate to the shores of the Yellow Sea in a single uninterrupted flight of 6,000 to 8,000 km (Battley *et al.* 2000, 2005; Rogers *et al.* 2010). Satellite telemetry has confirmed that a similar flight is made by Bar-tailed Godwits (Global Flyway Network; R. J. Gill, T. Piersma and colleagues in prep.). These enormous flights, lasting some 5–10 days, are fuelled by stores, especially fat, that the birds build up in the 1–2 months preceding migration (*e.g.* Piersma *et al.* 2005). Shorebirds almost double in mass before undertaking trans-equatorial migrations, so are strongly dependent on high-quality feeding grounds (Battley *et al.* 2000; Piersma *et al.* 2005b).

There can be little doubt that the Kimberley coastline does provide high-quality feeding grounds for shorebirds. It is dominated by very large tidal ranges (exceeding 9 m on many spring tides, and even higher in King Sound), and along much of the coast low tides expose extensive tidal flats, many kilometres wide. Tidal flats are the preferred foraging habitat for many shorebird species on the Kimberley coast, and over 15 of these species (including knots and godwits mentioned above) do not regularly feed in any other habitat during the non-breeding season. Moreover, surveys to assess the biomass and diversity of macrozoobenthos have demonstrated that potential shorebird prey is extraordinarily diverse and abundant in the tidal flats of Roebuck Bay (Pepping *et al.* 1999a, de Goeij *et al.* 2003)

and Eighty-mile Beach (Piersma *et al.* 2005a; Honkoop *et al.* 2006).

Shorebirds forage when walking or wading, and tidal flats are only accessible to them when the tide is low. High tides force them to sites known as roosts (whether they actually sleep there or not). Roost-choice studies in Roebuck Bay (Rogers *et al.* 2006b, 2006c) have demonstrated that potential roost sites are only suitable if they have a combination of physical attributes, including wet substrates (so shorebirds can avoid heat stress in exposed tropical conditions; Battley *et al.* 2003), open terrain (so approaching predators can be detected and avoided), and proximity to feeding areas (to keep commuting costs low). If suitable roost sites are unavailable, or are made inhospitable by frequent disturbance, shorebirds may be obliged to desert feeding areas (Rogers *et al.* 2006c). It is not known if roost site availability limits shorebird numbers in the Kimberley, but it is possible at some sites, as much of the Kimberley coastline is fringed by mangrove forests (Johnstone 1990) which are too dense for roosting shorebirds.

The roost choice studies in Roebuck Bay also enhanced shorebird surveying and monitoring projects in the region, as they led to an understanding of which seasons and tide conditions would lead to all shorebirds at specific sites using roosts which are accessible to counting teams (Rogers *et al.* 2006d). As a result, the main shorebird counts in the region are now carried out on carefully selected high tides between October and December (before the onset of wet season rains).

Methods

We examined shorebird count data from: (1) the Monitoring Yellow Sea Migrants in Australia (MYSMA) project outlined in Rogers *et al.* (2006d); (2) published literature and reports; (3) the shorebird count database at Birds Australia, which includes data from the AWSG's Population Monitoring Project, from the Atlas of Australian Birds and from the Shorebirds 2020 project. Except where stated, all results summarised here are from ground-counts at high tide roosts, carried out by experienced observers with binoculars and tripod-mounted telescopes. Experienced observers are essential for shorebird surveys in some sites of the Kimberley coast, where thousands, even tens of thousands, of shorebirds congregate in tightly-bunched and highly diverse flocks. Most results presented are from surveys carried out between late October and early December. This is considered the best time of year to survey shorebirds on the Kimberley coast because: (1) Most migratory shorebirds arrive on the coast of North Western Australia between August and mid-October (Minton *et al.* 2006; D.I. and K.G. Rogers, unpubl. data), so counts carried out earlier in the season are unlikely to represent peak numbers; (2) After wet-season rains begin, a varying and usually unknown proportion of coastal shorebirds begin to roost on clay-pans and other supra-tidal habitats that are usually inaccessible to human observers (Rogers *et al.* 2006b); moreover, access to even the more accessible roosts may become problematic in wet years when tracks are closed.

Site-specific notes on the survey data available, and the count methodology used, are given below. We only present the results of complete site counts. Shorebird sites usually have a number of different roost sites within them, and we only consider a site count to have been complete if every component roost was visited, in circumstances in which double-counting is unlikely to have occurred. Sources of error in shorebird counts have been reviewed by Rappoldt *et al.* (1979) and, in North Western Australia, by Rogers *et al.* (2006d). Both studies concluded independently that some of the variation observed in shorebird counts is caused by stochastic error, which can be quantified in a rigorous manner.

Genuine inaccuracies in counts can also occur. Most often, these are caused by flocks of birds being overlooked, and therefore maximum counts are a useful way to present shorebird count data, as they may be more representative of the number of birds that a site is capable of holding than mean counts skewed by individual counts in which birds were overlooked. On the other hand, maximum counts might themselves represent outliers. In this paper, we present maxima, but in the annotated species list (results) we also make specific notes in situations where there is a striking discrepancy between maximum and average counts.

We focus on Kimberley sites where at least one shorebird species has been found to occur in internationally significant numbers (Fig. 1) – *i.e.* >1% of the flyway population estimated by Bamford *et al.* (2008). They include Roebuck Bay, Eighty-mile Beach and three offshore island groups (Adele Island, Ashmore Reef and the Lacepedes). Most of these sites are difficult to access, and have not been surveyed many times. As data are thin, it was not possible to follow a uniform approach in summarising approximate numbers at each site. Data selection for each site is described below, and notes are provided on count methodology.

Roebuck Bay

Shorebird counts were initiated in Roebuck Bay (Fig. 2) in the early 1980's, but it was only in 1999 that it became conventional practice to carry out surveys in October to November, and only in 2004 when resources were first obtained to carry out counts at Bush Point (an important roost in the south of the bay) on a regular basis. Accordingly, in our summary of mean and maximum counts from Roebuck Bay we only present data collected since 2004, presenting the sum of complete counts carried out on the northern beaches and Bush Point on the same tide series. Two summer counts (late October to early December) and one winter count (June to July) were carried out annually in this period.

A series of beaches used by roosting shorebirds occur along the northern shores of Roebuck Bay, including Town Beach and Simpson's Beach adjacent to the Broome township. When conditions are dry (*e.g.* in the period before wet season rains begin in mid to late December), and tide height is between 6.8 and 9.0 m, these are the only roosts used by shorebirds from the northern tidal flats of Roebuck Bay (Rogers *et al.* 2006 b, c, d)[1]. Higher

[1] Optimal tide height in for shorebird counts in Rogers *et al.* (2006 b, c) was reported to be 6.0 to 8.2 m; since then the datum in Broome tide charts from the National Tidal Centre has been increased by 0.86 m, a convention we follow in this paper

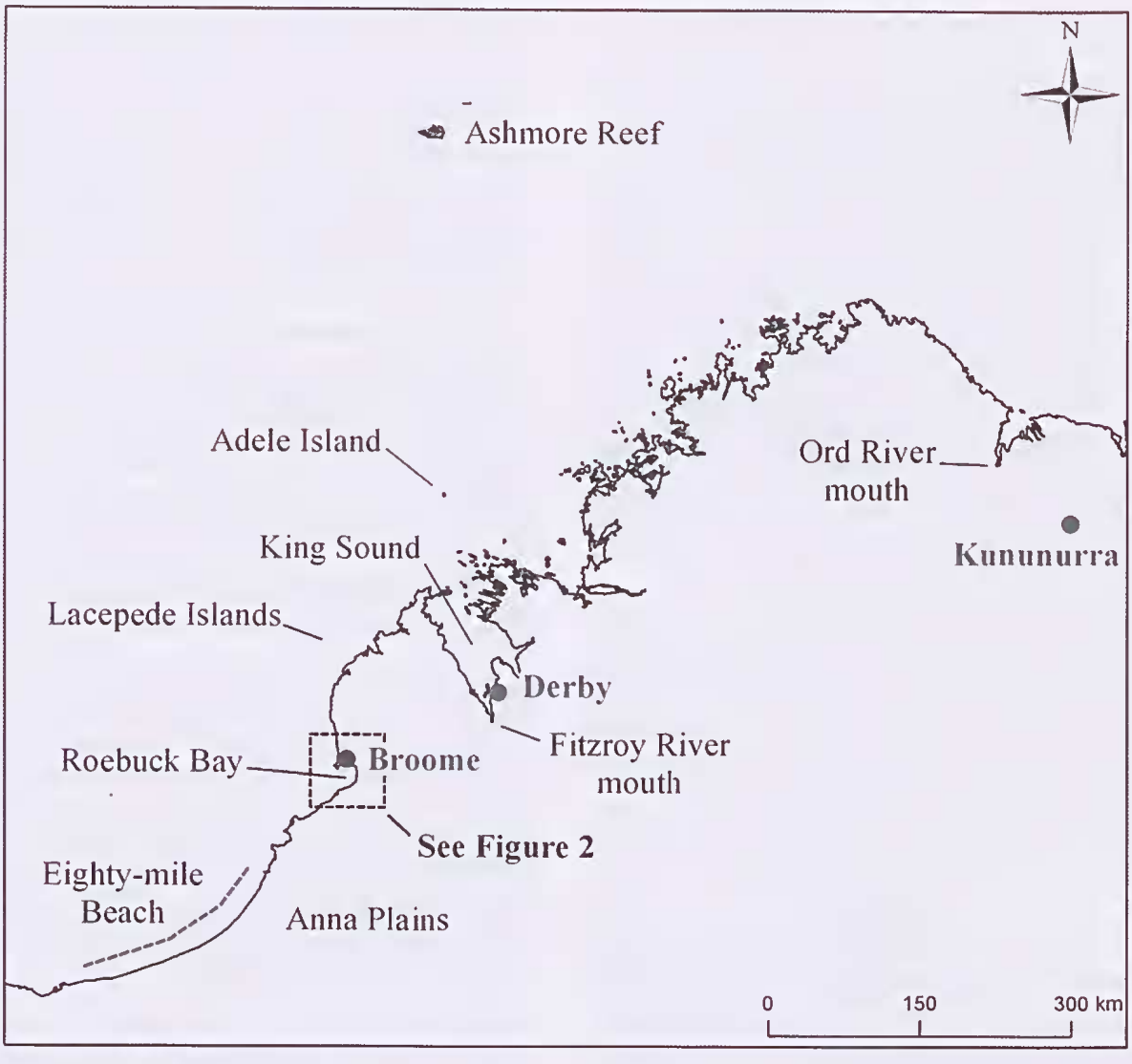

Figure 1. Shorebird sites of the Kimberley coast.

tides flow into mangrove clearings and claypans behind the mangroves; these become preferred roosting sites when wet, but are mostly inaccessible to human observers. During periods of neap tides, high tides are lower than 6.8 m, and are not high enough to push all shorebirds from the tidal flats. Tides between 6.8 m and 7.2m do not keep shorebirds on the northern beaches for long enough for adequate counts, so counts of the northern beaches of Roebuck Bay are carried out on tides between 7.2 and 9.0 m high.

Shorebirds foraging on the tidal flats in the southern half of Roebuck Bay do not roost on the northern beaches; instead they fly south to roost at or near Bush Point. Bush Point can be counted most repeatably on tides between 8.8 and 9.7 m high; on lower tides aerial and hovercraft surveys have shown that some shorebirds find roosts on sandbanks or mudbanks in front of the mangrove fringe which are very difficult for humans to access. Vehicle access to Bush Point is not possible on tides greater than 9.7 m high and such tides also create potential alternate roosting sites in the saltmarsh.

Radio-telemetry studies (Rogers *et al.* 2006 b, c) have shown that within a spring tide series, there is virtually no movement of Great and Red Knots to Bush Point from the northern beaches of Roebuck Bay. However, colour-band resightings indicate that some birds can move from the north to the south of Roebuck Bay over longer time frames (C J Hassell unpubl. data), with radio-telemetry suggesting these relocations typically occur during neap tides, when tidal flat areas are restricted and high tides are too small to be suitable for shorebird surveys (Rogers *et al.* 2006b. and unpubl. data). We therefore consider coupled counts of Bush Point and the northern beaches of Roebuck Bay on the same tide series (not separated by a neap tide series) to be complete counts of Roebuck Bay. A few shorebirds that sometimes roost in mangroves may be overlooked, (*e.g.* Common Sandpiper, and possibly some Whimbrel, Terek Sandpiper and Grey-tailed Tattlers) but both radio-telemetry and aerial surveys indicate that there are no other major roosts for shorebirds in the area in the tide conditions when we carry out surveys.

Eighty-mile Beach

Despite its name, Eighty-mile Beach is *c.* 220 km (*c.* 138 miles) long, and undertaking a complete count of the

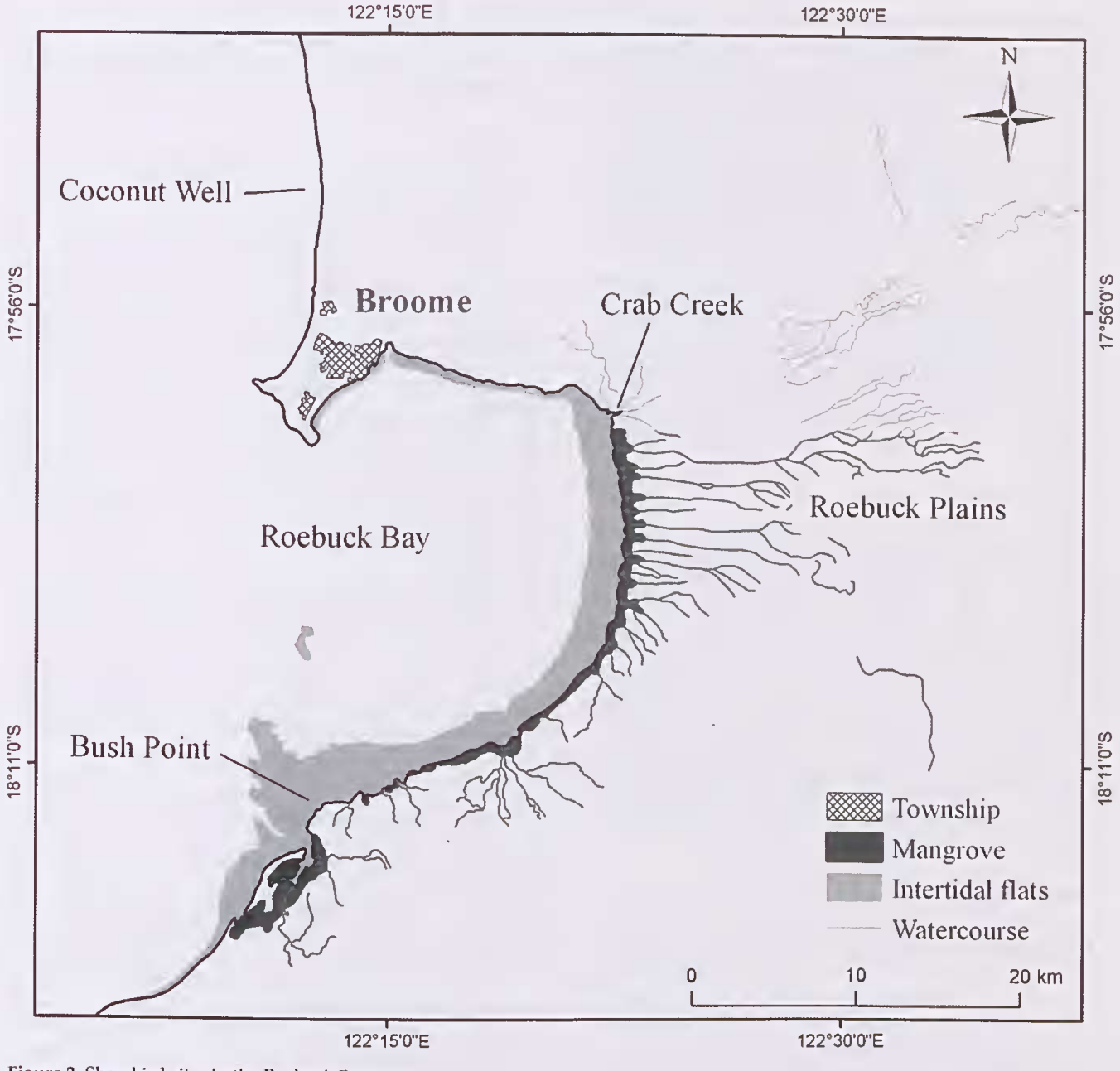

Figure 2. Shorebird sites in the Roebuck Bay area.

beach is difficult. In addition to the size and remoteness of the beach, counting shorebirds there requires exceptionally experienced teams, as the site has non-breeding populations of hundreds of thousands of shorebirds, occurring in very large mixed flocks.

Estimates of the numbers of shorebirds occurring on Eighty-mile Beach were first published in the late 1980's (Lane 1987, Watkins 1993), on the basis of ground counts of sections of the beach, supplemented by aerial surveys. The aerial surveys were used to assess total shorebird numbers on the beach, but it was not possible to identify shorebirds to species level from the air. To make the first estimates of numbers of each species on Eighty-mile Beach, Lane (1987) therefore made extrapolations from the species composition observed during the limited ground counts.

Complete ground counts of Eighty-mile Beach were first managed in the late 1990s, and there have still only been four complete ground surveys, in October 1998, November 2001, July 2003 and December 2008. These surveys showed that shorebird distribution is not consistent along all of Eighty-mile Beach. Some species are quite uniformly spread, but others occur in high densities along particular stretches of beach (differing between species). One such species with a particularly patchy distribution is the Red Knot; for example in 2008 the Red Knot population of 23,000 birds only used a 15 km stretch of Eighty-mile Beach (Rogers *et al.* 2009). As a result of the patchy distributions, previous estimates of shorebird numbers on Eighty-mile Beach based partly on extrapolation from limited ground counts must be treated with caution.

The complete surveys of Eighty-mile Beach also clarified the seasonal and tide conditions most suitable for surveying the site. Like Roebuck Bay, summer migrants are most repeatably counted about November,

after most or all birds have arrived from the northern hemisphere but before wet season and/or cyclone-associated rains have begun; in wet conditions vehicle access to the beach can become difficult and alternate roosting habitats can be created behind the coastal dunes. There are no tide charts available for Eighty-mile Beach but our experience is that time and height of high tides at this site are predicted reasonably well by tide charts for Roebuck Bay. Optimal tide heights for shorebird surveys are lower than those at Roebuck Bay, ideally between 6.8 and 7.9 m. On higher tides the beach becomes quite narrow in places, making it difficult to carry out counts without disturbing shorebirds and running the risk of double-counting them. Moreover, we suspect that on very high tides many shorebirds on Eighty-mile Beach make longshore movements so they can roost on broader stretches of beach, where they are not forced close to elevated dune fronts, which might be used for cover by predators.

Adele Island

This small (3.6 x 1.6 km), low-lying island is surrounded by extensive tidal sandflats, several km wide at low tide. Several ornithologists have visited the island and made notes or incomplete counts of migratory shorebirds (e.g Coate 1994, 1995, 1997; Swann 2002; Hassell 2003). Building on these experiences a four-person team carried out a complete count of shorebirds on the island in December 2004 (Boyle *et al.* 2005). Over a five day period they found that counts were best carried out on higher tides, which submerged sandbars on which shorebirds preferred to roost but were difficult to access. As the shorebirds were scattered it was necessary to split the team into two groups counting different areas simultaneously.

Ashmore Reef

A number of shorebird surveys have been undertaken on the islands and sandbanks of Ashmore Reef since 1979, but only four of these surveys are believed to have been complete, including counts of all high tide roosts on all islands. These surveys were undertaken in January 2002, February 2003, January 2005 and April 2010 (Swann 2005a, 2005b, 2005c and Clarke 2010). Complete counts can be conducted over a 4–5 day period and require predicted high tides at West Island, Ashmore Reef of between 3.5 and 4.0 m. This tidal range ensures birds are unable to occupy additional sandbanks that would be available on lower tides whilst also providing sufficient depths to access all islands and remaining sandbanks by water craft. We present the data summarised by Clarke (2010), who collated previous surveys and calculated maximum counts for the reef, in some cases including totals from partial surveys where they exceeded totals counted during the complete surveys.

Lacepede Islands

Data were available from six complete shorebird surveys on the Lacepede Islands: 15–19 December 1997 (Swann and Willing 1997), 1 September and 14 October 1998 and 9 October 1999 (AWSG unpubl. data), 26 September 2003 (AWSG unpubl. data) and 25 November 2004 (A Boyle, G Swann, T Willing, T Gale & L Collins unpubl. data). Although the islands are not large, a team of several persons is helpful for surveying these sites, as shorebirds need to be counted concurrently on four separate islands.

Other sites

There were aerial surveys for shorebirds of the entire mainland Kimberley coastline in the 1980's (Lane 1987, C D Minton unpubl.) and these were repeated in November 2008 (Kingsford *et al.* 2010). Both surveys were consistent in finding no major shorebird concentrations on the coast anywhere except Roebuck Bay and Eighty-mile Beach. The aerial surveys in the 1980's have influenced subsequent ground counts of shorebirds in the region, with observers only tackling the logistical difficulties of ground counts in areas which aerial surveys have suggested to be promising. For this reason, and also because of the remoteness of much of the coastline, there have been no systematic ground counts of shorebirds (that we are aware of) on any of the mainland coast between King Sound and the Northern Territory border. There has been patchy surveying of King Sound itself (Hassell 1997).

The south-west coast of the Dampier Peninsula, from Cable Beach to about Quondong, is regularly visited by Broome-based birdwatchers, but surprisingly few systematic shorebird counts have been carried out there and submitted to count databases. In this report we could only draw on the counts reported by Rogers *et al.* (2009); they were mostly consistent with the general qualitative experience of local birdwatchers in this area.

There is a stretch of coastline some 130 km long between Eighty-mile Beach and Roebuck Bay, with a number of shallow marine embayments that look potentially suitable for shorebirds. The only systematic ground counts of these sites that we are aware of were carried out in December 2008 (Rogers *et al.* 2009). The counts were made between 11th–13th December, on tides between 7.65 and 8.55 m high. Although the counts were 'cold', not informed by extensive former experience of the sites, they corresponded well with concurrent aerial survey and are considered reasonably accurate. We have pooled the data from several sites in our summary; details of the individual sites are given in Rogers *et al.* (2009).

Results

Shorebird numbers on the Kimberley coast

Maximum shorebird counts available for Kimberley coastal sites are presented in Table 1, along with East Asian – Australasian Flyway population estimates for each species from the literature. Forty-two shorebird species have been recorded on high tide roosts along the Kimberley coast, and 24 of these species occur on the coastline in internationally significant numbers (>1% of the flyway population). The combined population of all shorebird species on the Kimberley coast is 3.7 million shorebirds. These include *c.* 649,000 genuinely coastal shorebirds which forage on intertidal flats, 633,000 of which are migrants using the region as a non-breeding area; a further 16,000 are resident species. In addition, there have been counts of very large numbers of three

Table 1

Maximum shorebird counts at Kimberley coastline sites since 1999. Taxonomy and species order follows Christides & Boles (2008), except that migrant and resident species are separated; scientific names are given in the annotated species list in the results section. Flyway population estimates for migrants are from Bamford *et al.* (2008) except where otherwise stated in the text; population estimates for resident species are from Delany and Scott (2006). Species counts at internationally significant levels (>1% of the flyway population) are given in boldface.

	Eighty-mile Beach	Roebuck Bay	Adele Island	Ashmore Reef	Lacepede Islands	N of EMB	Dampier Peninsula	Total	1% thresh-hold	Flyway population estimate
COASTAL MIGRANTS										
Pacific Golden Plover	73	103	120	746	119	29	35	**1225**	1000	100–1000K
Grey Plover	**1585**	697	564	**1511**	106	209	55	4727	1250	125000
Lesser Sand Plover	162	71	671	32	94	9	75	1114	1400	140000
Greater Sand Plover	**64584**	**22318**	**2046**	**2559**	636	**3134**	**1423**	**96700**	1100	110000
Swinhoe's Snipe				1				1	250	25–100K
Black-tailed Godwit	52	**6780**	2	8				**6842**	1600	160000
Bar-tailed Godwit	**110290**	**25821**	**4819**	**4560**	**624**	**3414**	52	**149580**	3250	325000
Whimbrel	363	**1100**	69	536	16	220	59	**2363**	1000	100000
Eastern Curlew	**709**	**776**	57	4	32	74	5	**1657**	380	38000
Eurasian Curlew	1	1						2	400	4000
Terek Sandpiper	9820	**1522**	**604**	216	45	165	2	**12374**	600	60000
Common Sandpiper	6	19	4	9	8	12	26	84	250	25–100K
Grey-tailed Tattler	**14647**	**2173**	**5489**	**1791**	**2122**	448	110	**26670**	500	50000
Common Greenshank	2534	533	239	590	53	1	6	3957	600	60000
Nordmann's Greenshank	1							1	10	1000
Marsh Sandpiper	171	5	4	1				181	1000	100–1000K
Common Redshank	5	1	1	1	1			9	750	75000
Ruddy Turnstone	3480	**1044**	**1250**	**1708**	**2154**	402	196	10234	350	35000
Asian Dowitcher	2	**414**		8				**424**	240	24000
Great Knot	**169044**	**30361**	2945	1592	1055	1561	212	**206670**	3750	375000
Red Knot	**29679**	**2755**	51	55	150		27	**32717**	2200	105000
Sanderling	**3605**	**3235**	**449**	**1132**	158	423	**274**	9276	220	22000
Little Stint				1				1		
Red-necked Stint	**28443**	**16397**	**4107**	1530	625	998	385	**52485**	3250	325000
Pectoral Sandpiper			1					1	250	25000
Sharp-tailed Sandpiper	205	263		3	102	1	8	582	1600	160000
Curlew Sandpiper	7984	1601	493	850	365	1	1	**11295**	1800	180000
Broad-billed Sandpiper	35	196	21	1				**253**	250	25000
GRASSLAND MIGRANTS										
Oriental Plover	**144300**	**6431**		2		66	2	**150801**	700	70000
Little Curlew	**14200**	1297		50				**15547**	1800	180000
Oriental Pratincole	**2880000**	**21041**	1	1	1			**2901044**	20000	2880000
RESIDENT SHOREBIRDS										
Bush Stone-curlew		2						2		
Beach Stone-curlew	1	2		1				4	250	
Australian Pied Oystercatcher	809	**547**	48		58	132	36	**1630**	110	11000
Sooty Oystercatcher	25	34			43	5	39	**146**	75	7500
Black-winged Stilt	10	**381**	2	14		2		409	250	25–100K
Red-necked Avocet		30						30	1100	1700
Red-capped Plover	**6752**	**6531**	14		38	613	159	**14107**	950	95000
Black-fronted Dotterel	1						2	3	160	15500
Masked Lapwing				1			2	3	10000	
Australian Pratincole	9			2	1			12	600	60000
Total shorebirds	3493587	154482	24071	19516	8606	13919	3191	3717364		
Total coastal migrants	447480	118186	24006	19447	8465	13101	2951	633628		
Total grassland migrants	3038500	28769	1	53	1	66	2	3067392		
Total residents	7607	7527	64	18	140	752	238	16346		

grassland species (Oriental Pratincole, Oriental Plover and Little Curlew) which do not feed on the tidal flats of the Kimberley coast, but use surf- dampened beaches as a relatively cool loafing site in hot conditions.

The great majority of coastal shorebirds in the Kimberley region occur on two sites: Eighty-mile Beach (> 450,000 intertidal shorebirds; 19 species found in internationally significant numbers), and Roebuck Bay (> 113,000 shorebirds; 17 species found in internationally significant numbers). Offshore islands (Adele Island, Ashmore Reef) and the Lacepede Islands also have internationally significant numbers of several shorebird species, with counts of some of these species (notably Ruddy Turnstone, Grey-tailed Tattler, Sanderling and Grey Plover) being proportionately high compared to mainland sites. Surprisingly few shorebirds occur elsewhere along the Kimberley coast (see Discussion). An annotated species list below discusses the status of each species.

Coastal migrants

Pacific Golden Plover, *Pluvialis fulva*. No single Kimberley site holds internationally significant numbers of this species, but counts of >700 on Ashmore Reef are noteworthy, and the Kimberley coast as a whole supports more than 1% of the flyway population. Pacific Golden Plovers tend not to join large shorebird flocks in the Kimberley, instead occurring in small groups in localised sites; there are also records of the species foraging on inland plains in the company of Oriental Plovers, so it is likely that the number occurring in the Kimberley is underestimated.

Grey Plover, *Pluvialis squatarola*. Internationally significant numbers occur regularly on Eighty-mile Beach and Ashmore Reef. The large numbers (hundreds) occurring in Roebuck Bay and on Adele Island would once have qualified as internationally significant, before the flyway population size of Grey Plover was reappraised by Bamford *et al* (2008) and found to be larger than previously thought. Nevertheless, it could be argued that Roebuck Bay and Adele Island are of international importance to Grey Plovers, as more than 1% of the adult female Grey Plover of the East Asian – Australasian Flyway occur in these sites; this species shows strong differential migration in the East Asian – Australian flyway, and nearly all Grey Plover in Australia are female (Marchant & Higgins 1993; D I Rogers, C D T Minton, K-M Exo *et al.* in prep.). There is an historical count of 1300 Grey Plovers in Roebuck Bay, but no more than 700 Grey Plover have been seen in Roebuck Bay surveys since 2004.

Semi-palmated Plover, *Charadrius semipalmatus*. This vagrant has been recorded once during a shorebird count, on the shores of Roebuck Bay in the summer of 2010.

This individual had been present for a year and was the first Australian record on discovery. A second individual (the fourth Australian record) occurred briefly in Roebuck Bay while the first bird was still present (A.N. Boyle and G. Swann unpubl.)

Lesser Sand Plover, *Charadrius mongolus*. Although distinctive when examined closely, this species is easily confused with the similar Greater Sand Plover during shorebird counts. Previous reports of over 1000 in Roebuck Bay in 1990 and of 550 at Ashmore Reef prior to 1998 may have been influenced by misidentifications by observers who may, on the basis of eastern Australian experience, have incorrectly anticipated Lesser Sand Plover to be the more numerous of the two species. In fact Greater Sand Plovers far outnumber Lesser Sand Plovers in North Western Australia, and more recent surveys by teams with more local experience have been consistent in finding Lesser Sand Plovers to be uncommon and patchily distributed on the Kimberley coast and most offshore islands. No Kimberley sites are known to have internationally significant numbers of Lesser Sand Plovers, but confirmed counts of almost 700 on Adele Island (Boyle *et al.* 2005) are noteworthy.

Greater Sand Plover, *Charadrius leschenaultii*. Internationally significant numbers occur on Eighty-mile Beach, Roebuck Bay, Adele Island, Ashmore Reef and the Dampier Peninsula. Collectively, over 85% of the Flyway population of Greater Sand Plover occurs on the Kimberley coast.

Black-tailed Godwit, *Limosa limosa*. Internationally significant numbers occur in Roebuck Bay, mainly feeding on the soft tidal flats at the mouth of Crab Creek at low tide, and at high tide roosting on the adjacent northern beaches. Numbers there fluctuate, and summer counts since 2004 have ranged from 116 to 1975 birds (average 693). Higher counts have been made in the past (*e.g.* 6780 in November 2001; three counts of 2000–4000 in Feb–Dec. 1999). It is not known if the lower counts in recent years reflect declines, or variation typical for the species. Black-tailed Godwits also make use of fresh inland wetlands, and it is possible that the highest counts in Roebuck Bay occur in dry conditions when there is least wetland habitat inland.

Bar-tailed Godwit, *Limosa lapponica*. Internationally significant numbers occur in Roebuck Bay, Eighty-mile Beach, Adele Island and Ashmore Reef. Collectively Kimberley coastline and offshore island sites hold over 45% of the flyway population of Bar-tailed Godwits. The subspecies occurring in North Western Australia is the Siberian-breeding *menzbieri*, and it is likely that the Kimberley coast holds most of the non-breeding population of this subspecies. The eastern limits of the range of *menzbieri* are poorly known, but it is rare to absent in eastern Australia and New Zealand, where subspecies *baueri* predominates.

Whimbrel, *Numenius phaeopus*. Internationally significant numbers occur in Roebuck Bay, but it is relatively uncommon on Eighty-mile Beach and on most of the offshore islands of importance for other shorebird species. Unlike Roebuck Bay, these sites lack extensive mangrove stands. Whimbrel on the Kimberley coast seem to be most abundant near mangroves, where they forage for crabs both at low tide (on tidal flats) and often at high tide (at the interface of mangroves and saltmarsh). The species can also roost in mangroves at times, making it difficult to count; in Roebuck Bay the numbers seen setting off on northwards migration exceed those observed on high tide roosts. We think it is likely that available data considerably underestimate numbers on the Kimberley coast.

Eastern Curlew, *Numenius madagascarensis*. Internationally significant numbers occur in Roebuck Bay and Eighty-mile Beach; collectively the Kimberley coastline holds about 4% of the flyway population.

Eurasian Curlew, *Numenius arquata*. A vagrant; the only confirmed Australian records are from Eighty-mile Beach and Roebuck Bay.

Terek Sandpiper, *Xenus cinereus*. Over 20% of the flyway population occurs on the Kimberley coastline, mainly in Roebuck Bay and on Eighty-mile Beach.

Common Sandpiper, *Actitis hypoleucos*. This species occurs in low densities, does not typically roost in flocks, and prefers sites with narrow or steep shorelines, such as mangrove systems and sheltered rocky coastlines. Its numbers on the Kimberley coastline are therefore likely to be greatly underestimated during standard shorebird surveys.

Grey-tailed Tattler, *Tringa brevipes*. Over 50% of the flyway population occurs on the Kimberley coast. Over 35% of these birds occur on the tidal flats of small offshore islands (Adele Island, Ashmore Reef and the Lacepedes), and internationally significant numbers also occur on Eighty-mile Beach and Roebuck Bay.

Common Greenshank, *Tringa nebularia*. Internationally significant numbers regularly occur on Eighty-mile Beach, especially in the October–December period before wet season rains create alternate habitats in inland wetlands. Numbers in Roebuck Bay and Ashmore Reef also approach internationally significant levels.

Nordmann's Greenshank, *Tringa guttifer*. This endangered migratory shorebird has only been recorded twice in Australia. Both records are of single individuals on Eighty-mile Beach found during shorebird counts (Birds Australia Rarities Committee, cases 519 and 673).

Marsh Sandpiper, *Tringa stagnatilis*. A migrant which occurs mainly on inland wetlands during the non-breeding season. Small numbers (up to a few hundred on Eighty-mile Beach) occur on the Kimberley coastline, mainly in the October–December period when inland wetlands are most likely to be dry.

Common Redshank, *Tringa totanus*. Annual visitor in very small numbers; the non-breeding strongholds of this species are north of Australia. It occurs regularly at Crab Creek in Roebuck Bay.

Ruddy Turnstone, *Arenaria interpres*. The Kimberley coastline is used by almost 30% of the flyway population during the non-breeding season, and resightings of leg-flagged and colour-banded birds suggest that additional birds stage in the area during southwards migration. Over half the Kimberley population occurs offshore, on Adele Island, Ashmore Reef and the Lacepede Islands. Internationally important numbers also occur in Roebuck Bay and Eighty-mile Beach.

Asian Dowitcher, *Limnodromus semipalmatus*. The non-breeding stronghold of this species is on the coast of Sumatra, but internationally significant numbers have also been recorded in Roebuck Bay. The status of Asian Dowitchers in North Western Australia is puzzling. A feeding flock of 414 birds was recorded at the mouth of Crab Creek in Roebuck Bay in 2000 (Rogers *et al.* 2000); 212 were found in the same site a year later (C. J. Hassell pers. obs.) but there have been no other counts exceeding 150 birds. Nevertheless, this count was consistent with the tendency for Asian Dowitchers to be most abundant in Roebuck Bay in March/April, when counts on the northern beaches regularly approach 100 birds. Typically some non-breeding dowitchers remain on the northern beaches of Roebuck Bay during the austral winter, but (unlike all other migrant species in North Western Australia) numbers decline inexplicably during September and October, with very few being present in the October to December period.

Great Knot, *Calidris tenuirostris*. Internationally significant numbers occur in several sites on the Kimberley coast, notably at Eighty-mile Beach (which holds 45% of the flyway population) and Roebuck Bay (8% of the flyway population). Collectively over 55% of the flyway population occurs on the Kimberley coast during the non-breeding season.

Red Knot, *Calidris canutus*. Until recently, the flyway population of this long-distance migrant was thought to be about 220,000 (Bamford *et al.* 2008), but a recent revision showed the actual population is only *c.* 105,000 (Rogers *et al.* 2010). The Kimberley population (over 30% of the flyway population) includes at least 50% of the global population of subspecies *piersmai* from the New Siberian Islands. In the late 1980s the Eighty Mile Beach was estimated to support *c.* 80,000 Red Knot (Lane 1987, Watkins 1993), on the basis of partial ground counts supplemented by aerial survey. However, complete ground counts conducted since then have been consistent in finding only 20–30,000 Red Knot. We suspect that the high initial estimate was in error but cannot rule out the possibility that the discrepancy with subsequent counts has been caused by population decline.

Sanderling, *Calidris alba*. Over 30% of the flyway population occurs on the Kimberley coastline, with internationally significant numbers occurring in Roebuck Bay (mainly at Bush Point), Eighty-mile Beach, Ashmore Reef and the west coast of the Dampier Peninsula. We believe the only Dampier Peninsula count available to us to be an underestimate of the number of Sanderling that use this coastline, as regular sightings of over 500 Sanderling have been at one Dampier Peninsula site (Coconut Well; A. N. Boyle unpubl.), especially during southwards migration when some individuals stage in the region before migrating further south.

Little Stint, *Calidris minuta*. One record from Ashmore Reef during counts and occasional records elsewhere along the Kimberley coastline. This species is very difficult to distinguish from Red-necked Stint and is probably overlooked at times, but it is clear from banding studies that the species only occurs in the region as a vagrant.

Red-necked Stint, *Calidris ruficollis*. About 16% of the flyway population occurs on the Kimberley coastline, with internationally significant numbers on Eighty-mile Beach, Roebuck Bay and Adele Island during the non-breeding season. Resightings of leg flags suggest that additional Red-necked Stints may stage on the Kimberley coast during southwards migration.

Pectoral Sandpiper, *Calidris melanotus*. The single record on Adele Island was probably a disoriented staging

individual; the species typically prefers freshwater wetlands.

Sharp-tailed Sandpiper, *Calidris acuminata*. Numbers peak on the Kimberley coast about September to October. Some birds remain through the wet season, but many only stage in the area before migrating inland, or further south, for the non-breeding season.

Curlew Sandpiper, *Calidris ferruginea*. Internationally significant numbers occur on Eighty-mile Beach. The numbers occurring on Roebuck Bay and Ashmore Reef are probably also internationally significant, especially as there is evidence from banding studies suggesting that some individuals stage in North Western Australia during southwards migration; numbers observed in November counts may therefore not include all birds that depend on the area as a feeding ground while staging. There is an urgent need to review the flyway population of this species, as it has undergone serious declines since the 1980's in all Australian sites for which monitoring data are available (Gosbell and Clemens 2006).

Broad-billed Sandpiper, *Limicola falcinellus*. Numbers in Roebuck Bay approach internationally significant levels. Two hundred were counted by Broome Bird Observatory on the northern shores of Roebuck Bay on 25 October 2009; as the important roost at Bush Point was not visited at the time, it is likely that further birds were present in the bay.

Grassland migrants

Oriental Plover, *Charadrius veredus*. Although this plover forages on grasslands rather than tidal flats, large numbers are regularly seen at high tide coastal roosts on Eighty-mile Beach, and sometimes in Roebuck Bay. They use these sites as a thermal refuge in the middle of the day, as they can loaf on wet sand in a sea breeze, experiencing a much cooler microclimate than that of the plains where they feed in the morning, the evening and through the night. The highest ever count of 144,000 birds was made on a 75 km stretch of Eighty-mile Beach in February 2010 (Piersma and Hassell 2010). It exceeds the previous estimate of the flyway population of this species (70,000 birds, Bamford *et al.* 2008), which is clearly in need of review. There had been several previous counts of 30–50,000 Oriental Plover along the same stretch of Eighty-mile Beach. It is suspected that the higher count in February 2010 reflected count logistics, as this survey targeted Oriental Plovers (and Oriental Pratincoles) in the middle of the day. In contrast previous surveys targeted 'tidal flat' shorebirds on morning high tides, and were concluded by 9–10 am, before temperatures had risen sufficiently to force all Oriental Plovers from their grassland feeding areas.

Little Curlew, *Numenius minuta*. Like Oriental Plover, this species forages on grasslands, but sometimes uses beaches of Eighty-mile Beach and Roebuck Bay as a thermal refuge in the heat of the day. The highest counts on these beaches were made in February 2010 (Piersma and Hassell 2010), at a time when large grasshopper swarms were present in the area. There have been other periods in the past (*e.g.* 1985) when tens of thousands of Little Curlew were present on Anna Plains and Roebuck Plains (C.D. T. Minton, pers. obs.), but did not roost in large numbers on the coast because there were alternative thermal refuges beside freshwater wetlands.

Oriental Pratincole, *Glareola maldivorum*. This species made headlines in February 2004, when a team from the AWSG, on encountering unusually high numbers of pratincoles on Eighty-mile Beach, took the opportunity to charter a plane and undertake a systematic count. They recorded 2.88 million Oriental Pratincoles (Sitters *et al.* 2004) – an astonishing result given that the flyway population at the time was thought to be only 75,000 birds. At the time the high count was considered to be a one-off, caused by an unprecedented combination of high locust populations in the region and extraordinarily wet conditions through most of the rest of northern Australia. Since then, however, Piersma and Hassell (2010) have again encountered huge numbers of Oriental Pratincoles on Eighty-mile Beach, counting *c.* 515,000 Oriental Pratincoles along a 75 km stretch of beach in February 2010. Although such large numbers are not an annual occurrence, it now seems that Eighty-mile Beach may be used more regularly by huge numbers of Oriental Pratincole than was previously appreciated. Like Oriental Plovers, they do not forage on the tidal flats off Eighty-mile Beach; instead they forage over adjacent grasslands, but roost on Eighty-mile Beach during the hottest time of day.

Resident species

Bush Stone-curlew, *Burhinus grallarius*. A terrestrial species; the very occasional records on the shores of Roebuck Bay presumably represent disturbed birds from nearby pindan woodlands.

Beach Stone-curlew, *Esacus magnirostris*. This coastal specialist is under-represented in standard high tide shorebird surveys; it typically occurs solitarily or in pairs, not joining large shorebird flocks. Aerial surveys suggest that it occurs in low densities but is widespread along the Kimberley coast, using habitats such as beaches and reefs (with some nearby mangroves or other near-shore vegetation which can be used for cover) which do not support high densities of other shorebird species, and have not been a focus for shorebird surveys. Nevertheless, much of the Kimbeley coastline is dominated by rocky shores or extensive mangrove systems which are unsuitable for the species, and it is curiously absent from some sites (such as Eighty-mile Beach) where the habitat appears adequate. We do not think the Kimberley coast supports a large population of this species.

Australian Pied Oystercatcher, *Haematopus longirostris*. A coastal resident which nests on ocean beaches, mainly during the austral winter and spring, and can congregate in non-breeding flocks with other shorebird species during the wet season. The Flyway population estimate of 11,000 was made by Watkins (1993). Internationally significant numbers are regularly reported at Bush Point in Roebuck Bay (dominated by non-breeding subadult individuals). Eighty-mile Beach is also an internationally significant site for the species, but this was not recognised until 1999, as previous ground-counts of Eighty-mile Beach had not included the sections of the beach around Wallal Downs where Australian Pied

Oystercatchers are most abundant (perhaps because the low dunes behind this section of the beach are suitable for nesting).

Sooty Oystercatcher, *Haematopus fuliginosus*. A coastal resident which occurs mainly on rocky shores, though it can also be found on adjacent sandy beaches. Unlike the Australian Pied Oystercatcher, it prefers to nest on islands (such as the Lacepedes), with counts on the mainland being dominated by non-breeding flocks. The northern Australian subspecies *ophthalmicus* occurs in the Kimberley; it has been estimated to have a global population of 7,500 birds (Delany & Scott 2006). No single site in the Kimberley has been identified as having internationally significant numbers of Sooty Oystercatcher, but the region as a whole is likely to hold a large proportion of the flyway population, given that the species occurs at low densities along long areas of rocky coastline where no ground counts of shorebirds have been attempted.

Black-winged Stilt, *Himantopus himantopus*. Subspecies *leucocephalus* occurs as a resident from Australia to Indonesia, mainly in freshwater wetlands. Small numbers occur in some high tide roosts along the Kimberley coast, especially in Roebuck Bay where internationally significant numbers sometimes forage on sheltered tidal flats near Crab Creek. Much larger numbers, sometimes tens of thousands, can occur on freshwater wetlands on nearby Roebuck Plains and Anna Plains when water levels are suitable.

Red-necked Avocet, *Recurvirostra novaehollandiae*. Typically found in inland wetlands; small numbers occur with some regularity in Roebuck Bay, foraging on sheltered tidal flats near Crab Creek and joining flocks of Black-winged Stilt at high tide roosts. Occasionally numbers in the low hundreds have been observed (A.N. Boyle pers. obs.), but this has not yet happened when formal counts were being carried out.

Red-capped Plover, *Charadrius ruficapillus*. In dry conditions numbers on the Kimberley coast are augmented by birds from inland wetlands, leading to fluctuations in count totals. Nevertheless internationally significant numbers occur regularly on the shores of northern Roebuck Bay, Bush Point and Eighty-mile Beach, roosting with flocks of small migratory shorebirds such as Sand Plovers and Red-necked Stints. Internationally significant numbers breed on the supra-tidal claypans of Roebuck Bay (Rogers *et al.* 2001).

Masked Lapwing, *Vanellus miles*. Largely a grassland species, the few records of this species at high tide roosts are a very small portion of the total local populations.

Australian Pratincole, *Stiltia isabella*. Occasionally encountered on the Kimberley coast, but this species occurs mainly on inland plains and wetlands.

Population changes

Relatively few shorebird surveys have been conducted along much of the Kimberley coast, and for most of the region we do not have an adequate history of data collection to assess whether shorebird populations are changing. However, counts have been repeated a number of times at the two most important sites, Eighty-mile Beach and Roebuck Bay.

Three complete surveys of Eighty-mile Beach have been carried out during the non-breeding season. Shorebird numbers observed in the most recent survey, in December 2008, differed substantially from those on previous surveys in October 1998 and November 2001, although all surveys were undertaken using the same methods, in the period between shorebird arrivals and the onset of wet season rains (Rogers *et al.* 2008). The differences between these surveys are summarised in Table 2. Most migratory species (10 of the 13 most numerous migrant species) had declined in numbers in 2008, the exceptions being species that also use freshwater wetlands (Common Greenshank and Red-necked Stint), and one (Sanderling) that forages on ocean beaches as well as tidal flats. Species which are typically restricted to tidal flats during the non-breeding season had apparently all declined, and for some species the decrease in numbers was dramatic, with 2008 counts being at least 50% lower than in 2001. In contrast, resident coastal species such as Australian Pied Oystercatcher had increased in numbers.

We cannot yet assess whether parallel declines in shorebird numbers have been occurring in Roebuck Bay, as the February-centred counts carried out in Roebuck Bay until 2000 are not comparable to the more reproducible November-centred counts carried out since

Table 2

Numbers of the most abundant coastal shorebirds species (regularly >500 birds per count) during complete summer counts of Eighty-mile Beach. Species that declined between 2001 and 2008 are italicised.

	17–18 Oct 98	12–13 Nov 01	10–12 Dec 08	2008 total as % of 1999–2001 counts
Coastal Migrants				
Grey Plover	*1,416*	*1,585*	*1,146*	*72.3%*
Greater Sand Plover	*63,482*	*64,584*	*22,885*	*35.4%*
Bar-tailed Godwit	*110,290*	*97,403*	*51,719*	*46.9%*
Eastern Curlew	*709*	*552*	*423*	*59.7%*
Terek Sandpiper	*7,989*	*9,820*	*4,628*	*47.1%*
Grey-tailed Tattler	*10,436*	*14,647*	*7,950*	*54.3%*
Common Greenshank	1,738	2,432	2,534	104.2%
Ruddy Turnstone	*3,480*	*1,649*	*2,433*	*69.9%*
Great Knot	*158,082*	*169,044*	*128,653*	*76.1%*
Red Knot	*24,891*	*29,679*	*23,123*	*77.9%*
Sanderling	2,230	3,219	3,605	112.0%
Red-necked Stint	16,766	24,005	28,443	118.5%
Curlew Sandpiper	*2,859*	*7,984*	*3,292*	*41.2%*
Resident Shorebirds				
Australian Pied Oystercatcher	653	694	809	116.6%
Red-capped Plover	2,512	3,077	6,752	219.4%
Total coastal migrants	404,867	427,139	284,705	66.6%
Total Resident shorebirds	3,179	3,786	7,597	239.0%

2001; in addition, systematic counts of one of the most important roosts in the bay, Bush Point, did not begin until 2004. It is clear however, that the declines on Eighty-mile Beach have not been matched by corresponding increases in Roebuck Bay

Discussion

Taken as a whole, the Kimberley coast is an extraordinarily important region for shorebirds. It is used by over 3.7 million shorebirds, including 25 species which occur in the region in internationally significant numbers (*i.e.* > 1% of the flyway population). No other region in Australia, or indeed anywhere else in the East Asian Flyway, supports such large and diverse non-breeding populations (Bamford *et al.* 2008).

The total of 3.7 million shorebirds is somewhat skewed by three species (Oriental Plover, Little Curlew and Oriental Pratincole) which forage on grasslands rather than tidal flats; they were recorded in coastal surveys as they loaf on beaches of the Kimberley coast, exploiting the relatively cool microclimate of surf-dampened sand or mud to avoid thermal stress during mid-day heat. Whether these species are actually dependent on the Kimberley coast is debatable; they are certainly dependent on the near-coastal grasslands where they forage, but whether or not these sites would be exploited if there were not thermal refuges on nearby beaches is a question that has not been fully investigated. The availability of beach roosts may be of particular importance to Oriental Plover, which occurs in large numbers on the plains behind Eighty-mile Beach every year, and forages on bare and exposed plains which become especially hot during the day.

Even when these grassland species are excluded from consideration, the Kimberley coast ranks as the most important non-breeding area for shorebirds known in Australia and the East Asian – Australasian Flyway; it is used by over 649,000 shorebirds which forage in intertidal areas, including 22 species that occur in internationally significant numbers. Within the Kimberley region, the distribution of these birds is patchy, with over 90% of the coastal shorebirds occurring at just two sites: Eighty-mile Beach and Roebuck Bay. Both sites have enormous tidal flats which have been shown to have an abundant and diverse macrozoobenthos fauna, and therefore provide rich feeding grounds for shorebirds (Pepping *et al.* 1999a; Piersma *et al.* 2005)

The tidal flat systems surrounding Adele Island, Ashmore Reef and the Lacepede Islands are also important for some shorebird species, such as Pacific Golden Plover, Grey Plover, Lesser Sand Plover (Adele Island only), Grey-tailed Tattler, Ruddy Turnstone and Sanderling. In contrast, other species such as Black-tailed Godwit, Asian Dowitcher, Great Knot and Red Knot are relatively uncommon at the same sites. It is not known why the island sites are more attractive to some species than others, and benthic surveys may be needed to answer this question. We can put forward two hypotheses: (1) The coarse sand substrates surrounding the islands may be unsuitable for some shorebird species such as Black-tailed Godwit and Asian Dowitcher, which in Roebuck Bay forage only in soft sediments (Rogers 1999); (2) Some species may have patchily distributed prey, and may therefore require very extensive tidal flats in order increase their chances of locating profitable foraging areas. For example, Great and Red Knots feed mainly on bivalves which are swallowed whole, and tend to concentrate in patches where a recent spatfall has resulted in high densities of small bivalves with thin shells that are easily crushed in the gizzard (Rogers 1999).

No systematic ground counts of shorebirds have been carried out on the very long, and mostly remote stretch of coastline between the Dampier Peninsula and the Northern Territory. It is possible that more detailed surveying will reveal the presence of other small shorebird sites, and perhaps even some with internationally significant numbers of some species. However, aerial surveys of this coastline indicate that it is not inhabited by large numbers of shorebirds (Lane 1987, Kingsford *et al.* 2010, C.D. T. Minton and A.N Boyle pers. comm.), and we can be confident that there are no further sites to be discovered which are as important to shorebirds as Roebuck Bay and Eighty-mile Beach.

The absence of shorebirds on much of the northern Kimberley coastline is not unexpected, as many of the shorelines are rocky and steep, without extensive tidal flats; in some regions extensive mangrove forests (Johnstone 1990) make intertidal areas of the Kimberley shoreline unsuitable for shorebirds. Moreover, the presence of extensive tidal flats does not necessarily mean that shorebirds will be present in large numbers. For example, relatively few shorebirds occur in King Sound (at the mouth of the Fitzroy River, Fig. 1), although it is only 150 km from Roebuck Bay and has even larger tidal flats. In November 1997, a survey of Doctor Creek, a site within King Sound containing about half of the most promising looking shorebird habitat in the sound, revealed the presence of only 1156 shorebirds (Hassell 1997). Anecdotal reports from a benthos-sampling expedition that travelled over much of the remaining tidal flat area in King Sound by hovercraft in July 1998 (Pepping *et al.* 1999b) indicated that still fewer shorebirds were present on the outer flats. The benthos surveys carried out by this team indicated that the benthic fauna in King Sound was depauperate: it was far less diverse and numerous than that in Roebuck Bay, with particularly low densities of polychaetes and bivalves. The low benthos abundance (and the resultant low abundance of shorebirds) was attributed to the tidal and freshwater scouring that occurs in this system, with huge tides (>11 m) reworking the sediments, causing high water turbidity and sweeping fine-grained sediment into the open ocean. In addition wet season flows from the Fitzroy River cause enormous salinity fluctuations in King Sound which are likely to be fatal to many benthic species (Pepping *et al.* 1999b).

The relatively low numbers of shorebirds in some sites in the Kimberly are not easily explained. For example, we remain puzzled by the low shorebird numbers found on the 130 km coastline between the Ord River and the Northern Territory border. Hassell *et al.* (2006) found only 924 shorebirds here in an aerial survey in November 2005, consistent with the low counts recorded on three other aerial surveys in 1985 (C D T Minton, pers. obs.), October 2008 and November 2009 (A N Boyle, pers. obs.),

and also with the low counts of shorebirds in the adjacent Northern Territory sections of Bonaparte Gulf reported by Chatto (2003). Why shorebird numbers should be low here is a mystery to us; from the air the habitat appears to be very suitable for shorebirds, with extensive tidal flats, and far less tidal scouring or freshwater influx than in King Sound.

It is clear that conservation of the majority of shorebirds along the Kimberley coast depends on protection of a relatively small number of sites. Fortunately, by world standards these sites face relatively few immediate threats and are in good condition. Protected by their isolation, they have never been threatened by processes that have caused deterioration or loss of many tidal flat habitats overseas, such as land reclamation, large-scale shorebird hunting, urbanisation or intensive harvesting of shellfish. In addition, the large tidal ranges of the Kimberley coast should help to buffer the tidal flats from area reduction if global warming should result in sea-level rises.

There are nevertheless some conservation concerns in Roebuck Bay. Nutrient enrichment in sections of the bay near to Broome township has resulted in increasingly frequent blooms of cyanobacteria; there are indications that this has already influenced benthos composition in the tidal flats and foraging behaviour of Bar-tailed Godwits has changed as a result (Estrella *et al.* 2011).

Disturbance of shorebirds at roosts on the northern beaches of Roebuck Bay is also of concern. Roost studies from 1997–2000 demonstrated that disturbance levels at these sites are high, with birds often undertaking energetically costly alarm flights to escape potential danger from birds of prey and humans. In 2000, disturbance levels were approaching the point at which energetic costs of disturbance on the northern beaches were too high to make foraging in northern Roebuck Bay profitable for shorebirds (Rogers *et al.* 2006c). Since then, disturbance levels on the northern beaches have been measured in 2005/06 (Rogers *et al.* 2006e) and 2007/08 (Sitters *et al.* 2009). These surveys indicated that disturbance levels had increased since 2000, and also suggested that shorebird numbers on the northern beaches of Roebuck Bay are declining during the dry season, when disturbance levels are high because of increased numbers of human visitors and birds of prey (especially Brahminy, Black and Whistling Kites, which may in turn be increasing in numbers on the northern beaches due to increased availability of fishing scraps from visitors). It is a worrying situation, especially as the human population of Broome continues to grow. Continued monitoring of disturbance is required, along with an assessment of whether existing conservation measures (mainly public education through signposting) are effective enough to control disturbance levels. The recently announced designation of Roebuck Bay as a Marine Park may be important in providing mechanisms to control the amount of human disturbance in the bay.

Both the nutrient enrichment and increased disturbance levels now observed in Roebuck Bay are indicative of the type of challenges that shorebirds may face in this site as Broome continues to grow. Other conservation issues that may become important in the future include increased pressure for coastal development near Broome (such as a proposed marina near Broome Port), and increased shipping in the area, especially should a proposed LNG hub proceed. The environmental risks from increased shipping will need careful assessment and management, as the localised distribution of shorebirds on the Kimberley coast may make their populations very vulnerable to oil spills.

Although there is a need for continued vigilance, we believe the shorebird habitat on the Kimberley coast to be mostly in good condition. Nevertheless, there are indications that shorebird populations in the region may be declining. At Eighty-mile Beach, 10 of the 13 most numerous migrant species declined in numbers between 2001 and 2008, some declining to less than 50% of their previous levels. These differences between surveys are unlikely to have been caused by local movements of birds to sites outside the survey area, given the very large scale of complete Eighty-mile Beach counts (220 km of beach with no alternative roost habitats known). The shorebird declines are also unlikely to have been caused by local habitat changes to this near-pristine site. Rather, we think they are part of a flyway-wide phenomenon which has also caused serious declines in populations of migratory shorebirds in southern Australia (Gosbell and Clemens 2006), New Zealand (Southey 2009) and south-east Queensland (Wilson *et al.* in press).

The widespread nature of shorebird declines in non-breeding grounds of the East Asian – Australasian Flyway indicates that the causal factors lie outside the non-breeding areas. They are unlikely to have been driven by fluctuations in breeding success, given that the proportion of first year birds within North Western Australian and Victorian non-breeding flocks has shown no indication of persistent decline since the AWSG and the Victorian Wader Study Group began to record age-ratios systematically in the late 1990's (Rogers & Gosbell 2006; Minton *et al.* 2009). Instead, the declines are widely considered by shorebird biologists to be driven by loss of staging habitat used by shorebirds on migration. Enormous areas of tidal flats have been "reclaimed" (converted to land) on the Asian coast in the past 2–3 decades, including almost half of the tidal flats of the Yellow Sea, the most important region for staging shorebirds in our flyway (Barter 2002; Moores 2006; Bamford *et al.* 2008; Rogers *et al.* 2010). In some other flyways, deterioration or loss of staging areas has been shown to cause increased adult mortality and resultant population declines in shorebirds (*e.g.* Baker *et al* 2004; Burton *et al.* 2006, van Gils *et al.* 2006, Kraan *et. al.* 2010). Shorebird declines in the Asian – Australasian Flyway have not yet been studied to the same level of detail, but the same processes presumably occur.

The greatest conservation threats to the migratory shorebirds of the Kimberley coast probably lie overseas rather than in Australia, but that does not diminish our need to monitor the shorebird populations of the Kimberley coastline. Rather, it intensifies the need to conduct robust monitoring, as the data obtained are important as a barometer of the health of the entire flyway, and help to identify those species in most urgent need of conservation action. North Western Australia is also an ideal base for studies of the migration routes used by our shorebirds. A great deal has already been learned from banding studies (*e.g.* Minton *et al.* 2006, Rogers *et al.* 2010) and the recent development of geolocators and

satellite transmitters small enough to be carried by migrating shorebirds (*e.g.* Clark *et al.* 2010) will further improve our capacity to identify those staging areas in greatest need of protection. Finally, we must not become complacent about conservation of our shorebirds on a more local scale; as economic development proceeds in the Kimberley, and towns such as Broome continue to grow, it will be important to ensure that the shorebird sites of the Kimberley remain adequately protected.

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